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RESEARCH PAPER

A comparative assessment on regeneration status of indigenous woody plants in *Eucalyptus grandis* plantation and adjacent natural forest

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Abstract: Diversity, density and species composition of naturally regenerated woody plants under *Eucalyptus grandis* plantation and the adjacent natural forest were investigated and compared. Twenty plots, with an area of 20 m × 20 m for each, were established in both of *E. grandis* plantation and adjacent natural forest, independently. In each plot, species name, abundance, diameter and height were recorded. Numbers of seedling were collected in five sub-plots (4 m^2) within each major plot. A total of 46 species in the plantation, and 52 species in the natural forest, which belongs to 36 families were recorded. The diversity of species (*H'*) is 2.19 in the plantation and 2.74 in the natural forest. The density of understory woody plant was 3842 stems/ha in the plantation and 4122 stems/ha in the natural forest. The densities of seedlings in the natural forest and the plantation were 8101 stems/ha and 4151 stems/ha, respectively. High similarity of woody species composition was found between the natural forest and the plantation. The *E. grandis* plantation was found favoring the regeneration and growth of *Millitia ferruginia* and *Coffea arabica* in a much better way than other underneath woody species.

Keywords: *E. grandis*, natural forest; natural regeneration; plantation; woody species diversity

Introduction

Plantation forests, adjacent to exposed remnants of indigenous forests, can provide shelter, reduce edge effects, increase connectivity between forest fragments, and accommodate edge-specialist and generalist forest species that would benefit from any forest type (Christian et al. 1998; Norton 1998; Davis et al. 2000). Even if plantations do have such and many other uses, intensive monocultures of exotic plantations are widely viewed in a negative light in relation to biological diversity conservation (Carnus et al. 2003).

Among *Eucalyptus, Pinus, and Tectona,* which are the most commonly used species for plantation purpose throughout the world, *Eucalyptus* has attracted by far the most criticism (Evans 1992; FAO 2001), e.g, *Eucalyptus* spp. do not provide organic matter but deplete soil nutrients needed by agricultural crops, compete water resources with agricultural crops, suppress ground vegetation, and result in unsuitability to soil erosion control (Jagger and Pender 2000).

Some studies found that the number of seedlings, density of sapling, and the number of native species in Eucalyptus plantation forests were higher than those in their adjacent disturbed natural forests (Michelsen et al. 1996; Eshetu 2001). Eucalyptus were also found as a succession catalyst that facilitates the recolonization of some native flora through their influence on understory microclimate and soil fertility, suppression of dominant grasses, and provision of habitats for seed dispersing animals (Lugo 1992; Loumeto and Huttlee 1997; Parrotta et al. 1997; Eshetu 2001; Feyera and Demel 2001; Feyera et al. 2002; Mulugeta and Demel 2004; Mulugeta et al. 2004).

Generally, all *Eucalyptus* species may not have equal negative effects on the environment, undergrowth vegetation, and soil fertility, etc. Their effect may vary within different geographical areas, rainfall regimes and within species. The objectives of this study were to investigate the regeneration status of indigenous woody plants in *E. grandis* plantation and the adjacent natural forest. It was hypothesized that *E. grandis* plantation hosted more number of tree and shrub species than its adjacent natural forest.

Materials and methods

Site description

The study was conducted in Belete state forest (7°31' N, 36°33' E, 1978–2113 m above sea level) in the Jimma Zone of Oromia state, southwestern part of Ethiopia. The physical feature of the study area is characterized by a rugged topography, and dominated by gentle slopes and a localized steep slopes ranging from 4%–45%. The *Eucalyptus* plantation was established in 1975 in a

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2.5 m × 2.5 m spacing. The mean height and mean diameter of the plantation was 19.5 m and 30.9 cm in April 2006, respectively.

The study area has a uni-modal type of rainfall pattern with the highest rain occurring between January and April. The mean annual rainfall during the years 1968–2004 was 1547 ± 324.5 mm, with large interannual variability. The mean annual temperature during the years 1980–2004 was 19.3°C, with a mean minimum of 13.3°C to mean maximum of 23.3°C. The hottest months occur from September to November (maximum 27.8°C). While coldness, occur from June to August (minimum 12.8°C). The rocks in the study area consist of Precambrian rocks with a drastic nitosols soil type, and thus it has good potential for agriculture, good physical properties, stable structure, deep rooting volume, and high moisture storage volume (EMA 1988).

Sampling design and data collection

Sampling design

For vegetation data collection, in total of 40 major sample plots, with an area of 400 m^2 for each, were laid out along line transects, of which 20 in the natural forest and the remaining in the plantation forest. The distance between consecutive plots along a transect was 100 m, and the spacing between two adjacent transect lines was also 100 m. In each major plot (20 m × 20 m), five subplots (2 m × 2 m) were established. Four of these subplots were laid at the corners of the major plots, and the rest one at the center. A compass was used for the alignment of transects.

Vegetation data collection

Within the major plot, plant species were identified, and the diameters at breast height (DBH) of all trees were measured using a caliper. Total height of larger trees was measured using hypsometer. Number of individuals was also recorded in each plot. Data on number of species and number of seedling (height < 1 m) for all trees, shrubs and climbers were collected in each subplot. Voucher specimens of plant species were collected, pressed and identified in the National Herbarium of Ethiopia, Addis Ababa University.

Data analyses

Vegetation structure and diversity

The Shannon-Wiener Diversity Index (*H*′) was used to determine diversity of species in both the natural forest and plantation (Kent and Coker 1994).

$$H' = -\sum_{i=1}^{S} P_i \ln p_i \quad \cdots\cdots(1)$$

where *S* is the number of species, p_i, the proportion of the individual species to the total, n_i / N

The equitability (evenness) of species in *E. grandis* plantation and the adjacent natural forest was calculated using H'/H'_{max}, where H'_{max} is ln (natural logarithm) of *S* (number of species). Moreover, paired t-test was used to compare the species diversity (*H*′) of each plot in the natural forest and plantation forest (SAS 2003). In this analysis, the diversity index (*H*′) for each major plot of the natural forest and the plantation was considered as a replication. Data collected from each major plot and in each forest category were used for structural analysis. The seedling data was also analyzed in a hectare base. Similarity index of understory regenerated native woody species in the plantation and adjacent natural forest was calculated using Jaccard's similarity coefficient (Krebs 1989). The Importance Value Index (to know the distribution of species in the plantation and natural forest) (IVI), which is a sum of relative values of density, frequency and dominance, was also calculated for each species (Kent and Coker 1994).

Results

Vegetation characteristics

Floristic composition and diversity of species

In total of 55 species of trees, shrubs and climbers representing 36 families were recorded in both *E. grandis* plantation and the adjacent natural forest (Table 1). We totally recorded 52 species in the natural forest and 46 species in the plantation. Nine species were recorded only in the natural forest, while three species were recorded only in the plantation forest.

The diversity indexes (*H*′) of *E. grandis* plantation and its adjacent natural forest were 2.193 and 2.744, respectively. The t-test statistics (t 0.025 (38) = 2.025, t cal = 3.54) result also revealed that a significant difference existed in the species diversity (*H*′) between each plot of the natural forest and the *E. grandis* plantation ($P < 0.05$). Moreover, the species distribution was 0. 698 in the natural forest and 0.576 in the plantation

Vegetation structure and density of species

The number of tree species in the higher diameter class is less than that in the lower diameter class. The relative density of trees and shrubs of 1–5 cm diameter was 80% in *E. grandis* plantation and 70% in the adjacent natural forest (Table 2). The density of trees and shrubs (Height > 1m) was 4 122 stems/ha in the adjacent natural forest and 3 842 stems/ha in *E. grandis* plantation, while the density of seedlings (height ≤ 1 m) was 8101 stems/ha in the adjacent natural forest and 4 151 stems/ha in *E. grandis* plantation. The density of *G. saxifraga* in diameters of 1-5 cm was higher in *E. grandis* plantation (249 stems/ha) than in the adjacent natural forest (193 stems/ha). Similarly, the density of *M. ferruginea* in diameters of 1-5 cm was also higher in *E. grandis* plantation (164 stems/ha) than in the adjacent natural forest (89 stems/ha). *M. graciliipes* had 114 seedling stems per hectare in the adjacent natural forest and 131 seedling stems per hectare in the plantation (Table 3). Generally, 90.3% of the species in the *E. grandis* plantation and 79% of the species in the natural forest have less than 50 seedling stems per hectare. The density of coffee was 1022 stems per hectare in *E. grandis* plantation and 1042 stems per hectare in the adjacent natural forest (Table 3).

Table 1. List of the woody species found in *E. grandis* plantation and the adjacent natural forest in Belete state forest (7°31' N, 36°33' E) in the southwestern part of Ethiopia

Scientific name	Natural forest	Plantation forest
Acanthus eminens C.B. Clark.	X	X
Albizia grandibracteata Taub.	X	X
Albizia gummifera (J.F.Gmel.) C.A. Sm.	X	X
Allophyllus abyssinicus (Hochst.) Radlk.	X	X
Pouteria adolfi-friederici Rob. & Gilb.	X	-
Apodytes dimidiata E. Mey. Ex Benth.	X	X
Bersama abyssinica Fres.	X	X
Brucea antidysenterica J.f. Mill	X	X
Calpurnia aurea (Lam.) Benth.	X	X
Cassipourea malosana (Bak.) Alston	X	X
Catha edulis (Vahl) Forsk., ex Endl.	-	X
Celtis africana Burm.f.	X	X
Clausena anisata (Willd.) Hook. F. ex Benth	X	X
Coffea arabica L.	X	X
Cordia africana Lam.	X	X
Croton macrostachyus Hochst.ex A. Rich.	X	X
Diospyros abyssinica (Hiern.) White	X	X
Dombeya torrida (J.F.Gmel.) P.Bamps	X	-
Dracaena afromontana Mildbr.	X	X
Dracaena steudneri Schweinf. Ex Engl.	X	-
Ehretia cymosa Thonn.	X	X
Ekebergia capensis Sparrman.	X	X
Fagaropsis angolensis (Engl.) Dale	X	-
Ficus sur Forsk	X	X
Ficus thonningii Bl	X	-
Ficus vasta Forsk.	X	X
Flacourtia indica (Burm.f.) Merr.	X	-
Galiniera saxifraga (Hochst.) Bridson.	X	X
Glinus lotoides L.	X	X
Jasminum abyssinicum Hochst. Ex Dc.	X	X
Justicia schimperana (Hochest.ex Nees) T. Anders	X	-
Macaranga capensis (Baill.) Sim	X	X
Maesa lanceolata Forsk.	X	X
Maytenus gracilipes (loes.) Sebsebe	X	X
Millettia ferruginea (Hochst.) Bak.	X	X
Olea capensis L.	X	X
Olinia rochetiana A. Juss	X	X
Paveta abyssinica Fres.	X	X
Phoenix reclinata Jacq.	X	X
Phytolacca dodecandra L' Herit	-	X
Podocarpus falcatus Pilg.	X	-
Polyscias fulva (Hiern.) Harms	X	X
Premna schimperia Engl.	X	X
Prunus africana (Hook.f.) Kalkm.	X	X
Pterolobium stellatum (Forsk.) Chiov.	X	X
Rhamnus prinoides L'Herit	X	X
Rothmanniaurcelliformis (Schweinf. ex Hiern.)Bullock ex. Robyns	X	X
Rubus apetalus Poir	-	X
Schefflera abyssinica (Hochest.) ex A.Rich) Harms	X	X
Syzygium guineense (Willd.) DC.	X	X
Teclea nobilis Del.	X	-
Tiliacora troupinii Cufod.	X	X
Vepris dainellii (Pichi-Serm.) Kokwaro	X	X
Vernonia amygdalina Del.	X	X
Vernonia thomsoniana Oliv. & Hiern	X	X

Note: X indicates presence of the species

Table 2. Relative density and number of species in each diameter class in *E. grandis* plantation and adjacent **natural forest**

Diameter class (cm)	*E. grandis* plantation		Adjacent natural forest	
	Relative density (%)	Number of species	Relative density (%)	Number of species
1-5	81.2	39	69.7	42
5-10	11.5	25	16.9	32
10-15	4.4	14	6	26
15-20	1.9	7	2.6	21
20-25	0.2	2	0.6	6
25-30	0.2	2	0.7	9
30-35	0.3	3	0.3	5
35-40	0.1	1	0.6	5
40-45	0	0	0.2	4
45-50	0.1	1	0.1	2
50-55	0	0	0.4	4
55-60	0.2	2	0.1	1
60-65	0	0	0.4	3
65-70	0	0	0.1	1
>70	0	0	1.2	11

Table 3. Density of some selected woody species in *E. grandis* plantation and adjacent **natural forest**

No.	Species	Adjacent natural forest		*E. grandis* plantation	
		Density of trees/ha	Seed-lings /ha	Density of trees/ha	Seed-lings /ha
1	*Coffea arabica*	1042	7000	1022	3350
2	*Maytenus gracili-pes*	194	114	190	131
3	*Galiniera saxfraga*	193	51	249	53
4	*Teclea nobilis*	183	106	-	-
5	*Clausena anisata*	163	88	74	26
6	*Vepris dainellii*	161	16	3	-
7	*Justia schimperana*	133	49	-	-
8	*Diospyros abys-sinica*	90	16	8	10
9	*Millettia ferruginea*	89	6	164	30
10	*Clausena malosana*	79	11	4	5
11	*Glinus lotoides*	78	10	1	-
12	*Albizia gummifera*	61	50	53	21
13	*Paveta abyssinica*	39	14	42.5	35
14	*Calpurnia aurea*	3	-	35	6
15	*Jasminum abys-sinicum*	4	1	34	50
16	*Vernonia thom-soniana*	31	53	145	93

The relative density of *C. arabica* in *E. grandis* plantation is higher than in the adjacent natural forest. Similarly, the relative density of *M. ferruginea* in the natural forest is lower than the *E. grandis* plantation forest (Table 4.). Some species such as *A. gummifera, A. abyssinicus,* and *C. aurea* have lower relative density in the adjacent natural forest than in the *E. grandis* plantation. About 63% of the species recorded in the plantation and

67% of the species recorded in the natural forest had a relative density value of less than 1 (Table 4).

Table 4. Relative density, relative frequency, relative dominance and Importance Value Index (IVI) of trees and shrubs

No	Species	Relative density		Relative frequency		Relative dominance		IVI	
		Adjacent natural forest	*E.grandis* plantation	Adjacent natural forest	*E.grandis* plantation	Adjacent natural forest	*E.grandis* plantation	Adjacent natural forest	*E.grandis* plantation
1	*Acanthus eminens*	0.16		10		0.01		10.17	
2	*Albizia grandibracteata*	0.61		30		2.86		33.47	
3	*Albizia gummifera*	1.99	2.28	50	60	1.68	18.8	53.67	81.12
4	*Allophyllus abyssinicus*	0.12	1.09	15	25	0.01	3.17	15.13	29.26
5	*Apodytes dimidiata*	0.20	0.16	15	15	9.05	0.12	24.25	15.28
6	*Bersama abyssinica*	2.48	1.03	85	45	0.49	1.26	87.97	47.29
7	*Brucea antidysenterica*	0.10	0.04	10	5	0.25	0.19	10.35	5.23
8	*Calpurnia aurea*	0.08	1.52	5	30	0.03	1.80	5.11	33.32
9	*Cassipourea malosana*	2.56	0.16	40	10	0.77	0.06	43.33	10.22
10	*Catha edulis*		0.16		5		0.07		5.23
11	*Celtis africana*	0.81	0.60	35	25	2.65	0.73	38.46	26.33
12	*Clausena anisata*	5.28	3.21	70	50	0.56	1.27	75.84	54.48
13	*Coffea arabica*	33.94	45.02	100	100	4.92	18.8	138.90	163.80
14	*Cordia africana*	0.98	0.16	40	10	3.80	0.17	44.78	10.33
15	*Croton macrostachys*	0.89	0.49	60	25	3.85	3.57	64.74	29.06
16	*Diospyros abyssinica*	2.93	0.11	65	10	3.66	0.08	71.59	10.19
17	*Dombeya torrida*	0.12		15		0.07		15.19	
18	*Dracaena afromontana*	1.26	0.11	45	5	0.49	0.02	46.75	5.13
19	*Dracaena steudneri*	0.16	0.33	15	15	0.20	0.31	15.36	15.64
20	*Ehretia cymosa*	1.87	1.36	45	15	1.72	4.03	48.59	20.39
21	*Ekebergia capensis*	0.04	0.11	5	10	0.05	0.05	5.09	10.16
22	*Fagaropsis angolensis*	0.57		40		0.07		40.64	
23	*Ficus sur*	0.45	0.82	40	15	5.52	1.50	45.97	17.32
24	*Ficus thonningii*	0.04		5		0.12		5.16	
25	*Ficus vasta*	0.08	0.05	5	5	0.04	0.01	5.12	5.06
26	*Flacourtia indica*	0.16		20		0.33		20.49	
27	*Galiniera saxifraga*	10.56	11.69	90	70	1.57	3.70	97.04	83.98
28	*Glinus lotoides*	2.52	0.05	45	5	1.77	0.04	49.29	5.09
29	*Jasminum abyssinicum*	0.12	1.47	10	40	0.04	0.31	10.16	41.78
30	*Justitia schimperana*	0.65		25		0.03		25.68	
31	*Macaranga capansis*	0.13	0.05	10	5	0.04	0.31	10.17	5.36
32	*Maesa lanceolata*	0.81	0.71	45	15	1.79	2.95	47.60	18.66
33	*Maytenus gracilipes*	6.30	8.27	76	65	2.93	3.59	85.23	76.86
34	*Millettia ferruginea*	2.89	7.12	75	75	0.94	13.40	78.83	95.47
35	*Olea capensis*	0.37	0.6	30	35	1.51	10.10	31.88	45.68
36	*Olinia rochetiana*	0.04	0.27	5	20	0.03	0.42	5.07	20.69
37	*Paveta abyssinica*	1.26	1.85	65	45	2.94	0.70	69.20	47.55
38	*Phoenix reclinata*	0.04		5		0.13		5.17	
39	*Phytolacca dodecandra*		0.05		5		0.02		5.07
40	*Podocarpus falcatus*	0.04		5		0.25		5.29	
41	*Polyscias fulva*	0.12	0.27	15	25	4.90	0.80	20.02	26.07
42	*Pouteria adolfi-friederici*	0.28		20		0.08		20.36	
43	*Premna schimperia*	0.33	0.49	30	20	0.43	0.49	30.76	20.98
44	*Prunus africana*	0.53	0.22	30	15	0.72	0.04	31.25	15.26
45	*Pterolobium stellatum*	0.08	0.05	5	5	0.20	0.02	5.28	5.07
46	*Rhamnus prinoides*	0.53	0.11	15	5	0.01	0.01	15.54	5.12
47	*Rothmannia urcelliformis*	0.20	0.05	25	5	0.15	0.15	25.35	5.21
48	*Rubus apetalus*		0.11		10		0.01		10.12
49	*Schefflera abyssinica*	0.12	0.11	10	10	3.76	0.07	13.88	10.18
50	*Syzygium guineense*	1.87	0.05	70	5	30.50	0.02	102.40	5.07
51	*Teclea nobilis*	5.93		75		1.52		82.45	
52	*Tiliacora troupinii*	0.08		10		0.28		10.36	
53	*Vepris dainellii*	5.24	0.11	75	10	1.01	0.05	81.25	10.16
54	*Vernonia amygdalina*	0.24	1.14	10	30	0.06	4.94	10.30	36.08
55	*Vernonia thomsoniana*	1.02	6.31	25	45	0.27	1.79	26.29	53.09

Similarity of understory woody species between the adjacent *natural forest and the E. grandis plantation*

Similarity of woody species between plots is presented in Table 5. The minimum Jaccard's similarity index value is 0.19, while the maximum is 1.00. The highest similarity of species composition exists between plot 8 of the *E. grandis* plantation and plot 9 of the adjacent natural forest. The lowest similarity in species composition was recorded between plot 6 of the *E. grandis* plan-

tation and plot 13 of the natural forest (Table 5). Most of the plots score a similarity index value of above 0.50.

Importance values of the species

The Importance Value Index (IVI), ranges between 5.07 and 138.90 in the adjacent natural forest and 5.06 and 163.80 in *E. grandis* plantation. Importance values of *A. gummifera, M. ferruginea, and C. arabica* are much higher in *E. grandis* plantation than in the natural forest (Table 4). Whereas, the IVIs of *B. abyssinica, G. saxifrage, and M. gracillipes* are higher in adjacent natural forest than in *E. grandis* plantation. *Coffea arabica* has a 100% relative frequency in both the natural forest and the *E.grandis* plantation. Its relative density is 45.02 in *E. grandis* plantation and 33.94 in adjacent natural forest. It had also a relative dominance of 18.8 in the plantation and 4.92 in the natural forest. Generally, *Coffea arabica* in *E. grandis* plantation has a higher IVI (163.80) value, compared to that in the natural forest (138.90) (Table 4.).

A. gummifera, C. arabica, M. ferruginea, O. capensis, V. amygdalina, and E. cymosa have a relatively higher basal area in *E. grandis* plantation, compared to those in the natural forest. The relative frequencies of *A. gummifera, M. gracilipes,* and *C. anisata* are higher that 50% in both natural and plantation forests (Table 4). Nearly, 35% of the woody species found in the plantation has higher IVI values than those found in the natural forest.

Table 5. Jaccard's Coefficient of similarity in species composition of naturally regenerated woody plants between sample plots of the adjacent natural forest (NF) and *E. grandis* plantation (EG)

Stands	EG1	EG2	EG3	EG4	EG5	EG6	EG7	EG8	EG9	EG10	EG11	EG12	EG13	EG14	EG15	EG16	EG17	EG18	EG19	EG20
NF1	0.65	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
NF2	0.66	0.63	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
NF3	0.80	0.86	0.75	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
NF4	0.96	0.61	0.75	0.65	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
NF5	0.75	0.92	0.80	0.72	0.33	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
NF6	0.49	0.35	0.63	0.37	0.31	0.31	*	*	*	*	*	*	*	*	*	*	*	*	*	*
NF7	0.97	0.64	0.78	0.98	0.73	0.40	0.65	*	*	*	*	*	*	*	*	*	*	*	*	*
NF8	0.98	0.62	0.75	0.97	0.72	0.39	0.98	0.7	*	*	*	*	*	*	*	*	*	*	*	*
NF9	0.98	0.62	0.75	0.97	0.72	0.39	0.98	1.00	0.4	*	*	*	*	*	*	*	*	*	*	*
NF10	0.79	0.84	0.92	0.74	0.74	0.55	0.76	0.74	0.74	0.6	*	*	*	*	*	*	*	*	*	*
NF11	0.82	0.58	0.63	0.84	0.63	0.29	0.88	0.85	0.85	0.62	0.8	*	*	*	*	*	*	*	*	*
NF12	0.81	0.65	0.63	0.74	0.73	0.26	0.75	0.76	0.76	0.70	0.68	0.71	*	*	*	*	*	*	*	*
NF13	0.61	0.75	0.54	0.56	0.88	0.19	0.55	0.55	0.55	0.47	0.54	0.67	0.65	*	*	*	*	*	*	*
NF14	0.92	0.73	0.73	0.90	0.84	0.33	0.91	0.91	0.91	0.70	0.87	0.84	0.80	0.85	*	*	*	*	*	*
NF15	0.69	0.68	0.55	0.65	0.82	0.21	0.64	0.66	0.66	0.48	0.61	0.70	0.91	0.87	0.62	*	*	*	*	*
NF16	0.79	0.60	0.61	0.80	0.64	0.28	0.84	0.80	0.80	0.62	0.98	0.65	0.56	0.84	0.61	0.81	*	*	*	*
NF17	0.95	0.69	0.74	0.94	0.79	0.36	0.96	0.96	0.96	0.72	0.93	0.78	0.70	0.97	0.76	0.90	0.85	*	*	*
NF18	0.92	0.63	0.84	0.87	0.65	0.76	0.89	0.88	0.88	0.82	0.77	0.67	0.48	0.80	0.55	0.74	0.86	0.8	*	*
NF19	0.68	0.83	0.78	0.66	0.72	0.31	0.71	0.67	0.67	0.84	0.80	0.64	0.52	0.71	0.51	0.82	0.75	0.68	0.58	*
NF20	0.98	0.62	0.75	0.98	0.72	0.38	0.99	0.78	0.73	0.74	0.84	0.76	0.55	0.91	0.66	0.79	0.95	0.88	0.66	0.8

Discussion

Floristic composition and diversity

The result of species diversity index indicate that the adjacent natural forest is more diverse than that of *E. grandis* plantation, and the species distribution in the adjacent natural forest (0.698) was more even than that of the *E. grandis* plantation (0.576). However, in the present study, the number of species recorded in the *E. grandis* plantation was much higher than that recorded in other exotic plantation species elsewhere in Ethiopia. Feyera and Demel (2001) recorded a total of 37 naturally regenerated woody species under *E. globulus, E. saligna, P. patula and C. lusitanica* on the central highlands of Ethiopia. Similarly, Eshetu and Olavi (2003) recorded a total of 22 native woody species in Eucalypt plantations in Menagesha, where there was remnant natural forest, and 20 native woody species in Eucalypt plantation in Chancho, where natural forests were absent. This difference might be associated with the species pool available in the surrounding natural forest, local climatic conditions and effects of the plantations on the different tree species.

Vegetation structure and density

The DBH structure of species can reveal the population dynamics. Therefore, based on diameter class distribution and density, the effects of plantation and natural forests on the recruitment of different species can be inferred. With increase in diameter class, the number of species decreased both in natural forest and *E. grandis* plantation considerably (Table 2). Therefore, in both of the natural forest and the plantation, the tree species in lower diameter classes are dominant. Trees in the higher diameter classes are few in *E. grandis* plantation, due to the age of the plantation, which is 31 years old.

Some species, such as *G. saxifrage* and *M. ferruginea,* have a relatively higher number of seedling and a higher density in *E. grandis* plantation, compared to those in the natural forest (Table 3). Therefore, this result may indicate that these species are eco-friendly and competent in *E. grandis* plantation. It may also indicate that, as an overstory tree, the plantation fosters the natural regeneration and growth of these species. Scientific evidences indicate that, some Eucalyptus plantations have the potential in enhancing the recruitment, establishment, and successions of certain native woody species (Loumeto and Huttlee 1997; Eshetu

2001; Feyera et al. 2002; Mulugeta and Demel 2004). On the other hand, some species, which had good diameter class distribution in the natural forest, were not found in the *E.grandis* plantation. This may show that *E. grandis* plantation might have a negative effect on the undergrowth of some species, while it favors the others.

Similarity of understory woody species between the natural forest and the plantation

The present study indicates that a high similarity of woody species composition exists between the natural forest and *E. grandis* plantation, for most of the plots. This might be for the uniform climatic condition of the area, the available species pool in the surrounding and impact of the plantation in it's underneath woody vegetation. The finding of this study is contrary with the results of some studies conducted in Ethiopia (Feyera et al. 2002), which reported low similarity among different plantations and the adjacent natural forest. The age of the plantation, the intensity of light reaching in the forest floor and the amount of rain fall received by the area may influence understory plant distribution.

Importance values of species

The IVI is considered to show greater ecological significance in plant distribution than in absolute density (Fosberg 1961). *Coffea arabica* found in *E. grandis* plantation has higher IVI and basal area than that in the natural forest. This indicates that the plantation favor the coffee plant distribution in its understory. The IVI result indicates that the *E. grandis* plantation as an overstory tree facilitates and fosters the distribution of *A. gummifera, A. abyssinicus, C. aurea, J. abyssinicum, M. ferruginea, O. capensis* and *V. thomsoniana* in its underneath. While, *B. abyssinica*, C. *malosana*, *C. anisata*, *C. african*, *C. macrostachys*, *D. abyssinica*, *D. afromontana*, *E. cymosa*, *F. sur*, *G. lotoide*, *M. lanceolata*, *P. abyssinica*, *P. schimperi*, *P. africana*, *R. prinoides*, *R. urcelliformis*, and *S. guineense* in the natural forest has higher IVI value than in *E. grandis* plantation forest.

Conclusion

Overall, the findings indicated that the effect of plantations on the regeneration of indigenous woody plants varied depending up on geographical location of the plantation, amount of rainfall, type of species and species pool in the surrounding. Moreover, some species have regenerated successfully in the plantation, while others were not. This indicated that, *E. grandis* as an overstory tree threats the natural regeneration of different woody species under its canopy, to different extents.

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